2-2016

Modernising an Underground Gas Drainage System in Response to Increased Production and Gas Content

Andrew McInerney
Anglo American Coal

Miles Brown
Drive Mining Pty Ltd

MODERNISING AN UNDERGROUND GAS DRAINAGE SYSTEM IN RESPONSE TO INCREASED PRODUCTION AND GAS CONTENT

Andrew McInerney[1] and Miles Brown[2]

ABSTRACT: This paper highlights a successful step change in the management of increasing gas contents and compressed drainage timeframes. The improvements have overcome safety risks concerned with a system not suitable for handling the required gas loading for current and future production targets. The paper discusses how the upgrades manage increasing seam gas content, high rig drilling rates, record development and longwall performance. Improvements to the system included specific design to suit continuity, in-seam hole stability, predicted peak gas flows, drilling and drainage direction, infrastructure type and capacity, formation of empirical gas decay curves and fines and water removal from the system. Using data captured from the commencement of the upgrade, steps toward an efficient and malleable long and short term design and planning tool have been taken. Variable flow rates has led to the investigation of high fluctuation of gas capture, moving away from traditional prediction methods and relying on analysed mine specific data.

INTRODUCTION

Anglo-American's Grasstree Underground Mine operates the German Creek Seam in the Bowen Basin. Production for 2015 is approaching 10Mt. Underground in-seam gas drainage with only two in-seam drilling rigs is utilised to drain the German Creek seam. With virgin gas contents approaching 16m3/t in the German Creek Seam and with Methane as the predominant gas, the management task is large.

Increased production with increasing gas content is the real challenge for Grasstree's underground in-seam gas drainage management team. In April 2015, following incidents involving gas emissions at drill stubs and development faces, the complete system needed an overhaul. This paper quantifies all the changes that have been introduced and discusses the intense reconciliation that occurs to ensure all changes are successful. The system will only be deemed successful if safety concerns are mitigated and predicted values are achieved. Hence by managing safety as the primary objective for changes to gas drainage, the technical improvements at the site have followed. Additionally any changes to the Underground In-seam (UIS) drainage system must cater for ever changing geological situations. The drainage designs and drainage infrastructure used require flexibility within their designs to suit all situations that are foreseen. Permeability, dykes, faults, gas content all vary in size and eliminate the ability of one design fits all.

APPROACH FOR UIS GAS DRAINAGE

To achieve change there must be a solid framework, which provides a clear flow path to success. This framework needs to outline all principles that provide the solution. The two over riding key governances for ensuring that gas drainage is effective at Grasstree Mine are;

- Science – where gas drainage rates, gas flows, gas pressures and business continuity values are predictable
- Design – where all potential safety, geological and structural risks are engineered to as low as possible.

[1] *Gas Drainage Engineer, Grasstree Mine , E-mail: andrew.mcinerney@angloamerican.com, M: 0412030559,*
[2] *Director Drive Mining Pty Ltd, 0458768620, E-mail: drivemining@bigpond.com,*

The Grasstree underground gas drainage upgrade was aimed at creating a "Gas Drainage System" that is transparent in all its designs and all its predictions. The system is best shown in Figure 1.

The key principles to be continually used for an effective scientific approach are;

- Prediction
- Continuity
- Monitoring

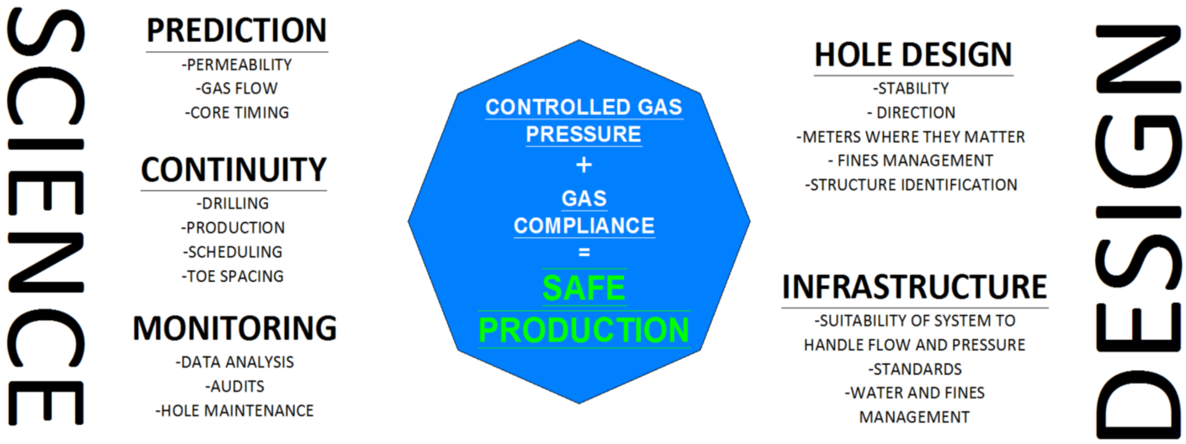

Figure 1: Schematic Gas Drainage System

SCIENCE – Underground gas drainage

Prediction

Utilising first principles to form an operational design program requires understanding on how drilled drainage holes actually react. This can be done with or without permeability data. Analysing hole flow data from existing underground in-seam holes, where known virgin gas contents is the primary method. This data along with monitoring the hole right through to the compliance core result can create a base decay curve. Once the decay curve is developed, and for Grasstree there are two distinct curves used for predicting flows, the other principles are applied to estimate hole flows.

Principles for hole flow estimation and subsequent drainage decay include;

1. Drilling rate – metres/day or metres per week
2. Hole spacing – this is the variable when determining continuity requirements
3. Seam thickness
4. Virgin Gas Content and target Gas Content
5. Hole length
6. Decay Curve (Figure 2)

	Per 100m	Per "X"	Low Perm Zone
M3/t	Flow l/sec	Flow l/sec	
0	0	0	0
1	0	0	0
2	0.5	6	3
3	1.5	18	10
4	3	35	19
5	4.25	50	28
6	6	71	39
7	8	94	52
8	10.5	124	68
9	14	165	91
10	16.5	195	107
11	20	236	130
12	23	271	149
13	26	307	169
14	29	342	188
15	31	366	201
16	32	378	208

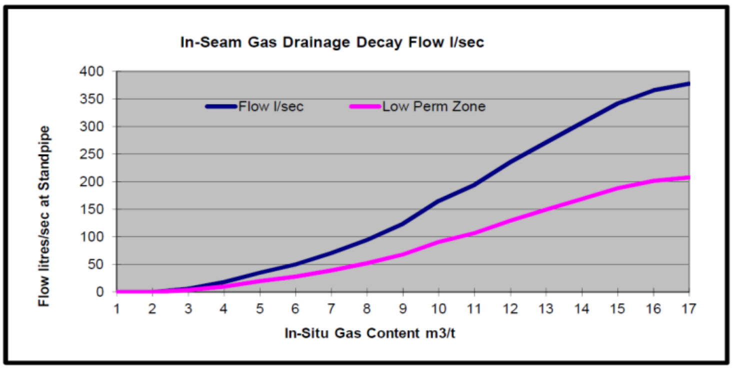

Figure 2: UIS design decay curve

The output from the design program is estimated individual hole gas flows and total site gas flow profile. (Figure 3). This information allows for future tracking of hole performance.

Year	Week Ending																						Week Ending						
Month	3-Oct	10-Oct	17-Oct	24-Oct	31-Oct	7-Nov	14-Nov	21-Nov	28-Nov	5-Dec	12-Dec	19-Dec	26-Dec	2-Jan	9-Jan	16-Jan	23-Jan	30-Jan	6-Feb	13-Feb	20-Feb	27-Feb	5-Mar	12-Mar	19-Mar	26-Mar	2-Apr	9-Apr	16-Apr
Total Flow	0	139	615	1059	1214	1084	902	748	625	537	467	413	367	327	286	245	216	186	170	157	146	140	136	134	132	130	128	23	22
Target Source																													
Hole 1	0	139	355	273	205	152	109	95	82	69	58	52	45	38	33	28	23	20	19	19	19	19	19	19	19	19	19		
Hole 2		0	125	285	236	190	148	112	88	75	65	58	50	45	38	35	30	26	24	20	18	17	17	17	17	17	17		
Hole 3		0	135	290	225	180	135	109	87	75	63	53	47	41	34	27	23	20	19	19	19	19	19	19	19	19	19		
Hole 4 (Assume Lowperm)			0	115	200	165	131	105	85	68	57	52	47	40	34	28	24	20	18	17	16	16	16	16	16	16	16		
Hole 5 (Assume Lowperm)			0	96	187	149	123	98	80	73	65	55	50	44	39	32	26	21	19	18	17	17	17	17	17	17	17		
Hole 6 (Assume Lowperm)				0	78	122	118	101	91	79	68	59	50	46	42	37	34	30	26	22	19	17	16	16	16	16	16		
Hole 7 (Assume Lowperm)				0	83	126	138	128	112	98	91	84	78	73	66	58	56	49	45	42	38	35	32	30	28	26	24	23	22
												5m3/t		Intersection															
												3m3/t		Coring															

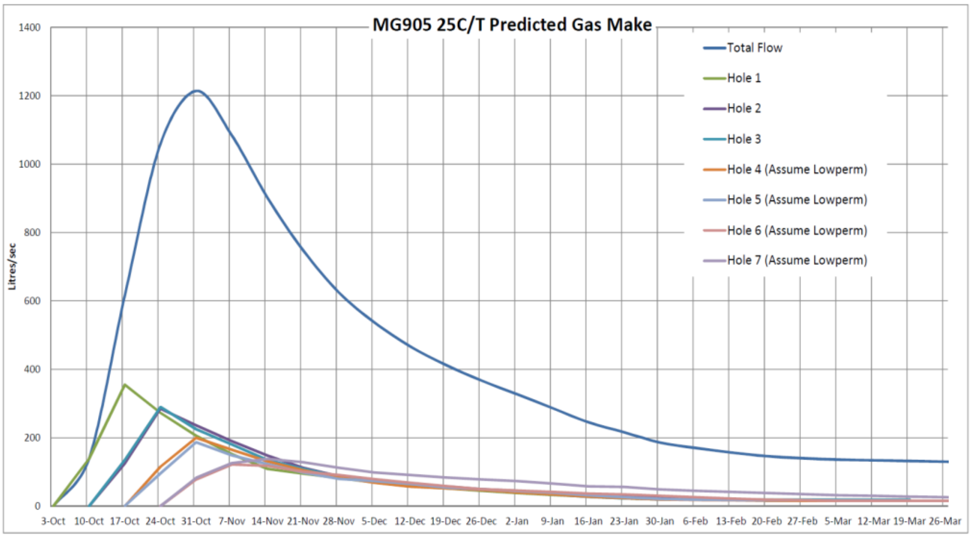

Figure 3: Predicted gas flow

Continuity

Gas Drainage continuity with development is achieved using the Grasstree gas drainage design program in conjunction with the mine production profile. The system is used for both single holes and drill sites and is also used for Life Of Mine (LOM) continuity. Life of Mine planning becomes a simple task of ensuring the correct spacing is applied to achieve continuity. The following two figures represent the planning spreadsheet tool for an individual drill site.

Drill Site	Target Zone	Start	Finish	# Holes	# holes including branches	Hole spacing	Actual Drilling length m's	Drilling length with contingency 20%	Drilling Rate m/week	Time to drill holes Weeks	Virgin Gas Content	CH4 %	CO2 %	Target Gas Content
13C/T 505	**506 9.5-13.5C/T**													
Hole 1 - Inbye	13 to 13.5	25/06/2015	27/06/2015	1	2	35	850	1020	3000	0.3	14	99	1	3
Hole 2	12.5 to 13	28/06/2015	30/06/2015	1	2	35	770	924	3000	0.3	14	99	1	3
Hole 3	12 to 12.5	1/07/2015	3/07/2015	1	3	30	860	1032	3000	0.3	14	99	1	3
Hole 4	11.5 12	4/07/2015	7/07/2015	1	3	30	790	948	3000	0.3	14	99	1	3
Hole 5	11 to 11.5	8/07/2015	11/07/2015	1	3	15	1110	1332	3000	0.4	15	99	1	3
Hole 6	11	12/07/2015	15/07/2015	1	3	15	980	1176	3000	0.4	15	99	1	3
Hole 7 - Outbye	LW Block	16/07/2015	18/07/2015	1	3	45	720	864	3000	0.3	15	99	1	3

Figure 4: Planning spreadsheet A

Drainage continuity with development is achieved by modifying the drainage hole design to suit the variable permeability, quanitified by specific gas decay curves, to set a hole spacing that achieves a planned gas drainage target content of approximately 3 m^3/t.

Drill Site	Target Zone	Area to Drain m2	Ave Seam Thickness	Tonnes Coal to Drain	Vol of gas to remove m3	Start date of gas Flow to pipe	Expected Time to drain to target (Days)	Required Finish date to Drain to target	Required time to drain to target	Continuity with Development at commencement of Zone	Initial PEAK total flow from holes (total) l/sec	Total flow from holes at 3m3/t	Probable Gas Content when Mined m3/t
13C/T 505	**506 9.5-13.5C/T**												
Hole 1 - Inbye	13 to 13.5	24700	2.7	93366	1027026	28/06/2015	134	16/12/2015	9/11/2015	37	411	17	2.8
Hole 2	12.5 to 13	17700	2.7	66906	735966	1/07/2015	104	7/12/2015	13/10/2015	54	379	16	2.75
Hole 3	12 to 12.5	27000	2.7	102060	1122660	4/07/2015	143	28/11/2015	24/11/2015	3	423	18	3
Hole 4	11.5 12	25400	2.7	96012	1056132	8/07/2015	146	19/11/2015	1/12/2015	-12	389	16	3.25
Hole 5	11 to 11.5	15400	2.7	58212	698544	12/07/2015	117	10/11/2015	6/11/2015	4	315	13	3
Hole 6	11	12800	2.7	48384	580608	16/07/2015	110	1/11/2015	3/11/2015	-2	278	11	3
Hole 7 - Outbye	LW Block	25100	2.7	94878	1138536	19/07/2015	161	15/03/2016	27/12/2015	79	372	15	2.5

Figure 5: Planning spreadsheet B

M3/t Start	M3/t End	time days	Years	Low perm Days
6	3	75.51	0.21	137.3
7	3	87.98	0.24	160.0
8	3	97.20	0.27	176.7
9	3	103.79	0.28	188.7
10	3	108.78	0.30	197.8
11	3	112.46	0.31	204.5
12	3	115.35	0.32	209.7
13	3	117.84	0.32	214.3
14	3	120.09	0.33	218.3
15	3	122.23	0.33	222.2
16	3	124.33	0.34	226.1

M3/t Start	M3/t End	time days	Years	Low perm Days
6	5	17.08	0.05	31.1
7	5	29.54	0.08	53.7
8	5	38.77	0.11	70.5
9	5	45.36	0.12	82.5
10	5	50.34	0.14	91.5
11	5	54.03	0.15	98.2
12	5	56.91	0.16	103.5
13	5	59.41	0.16	108.0
14	5	61.66	0.17	112.1
15	5	63.80	0.17	116.0
16	5	65.90	0.18	119.8

Figure 6: UIS Design Drainage time to 5m^3/t and 3m^3/t

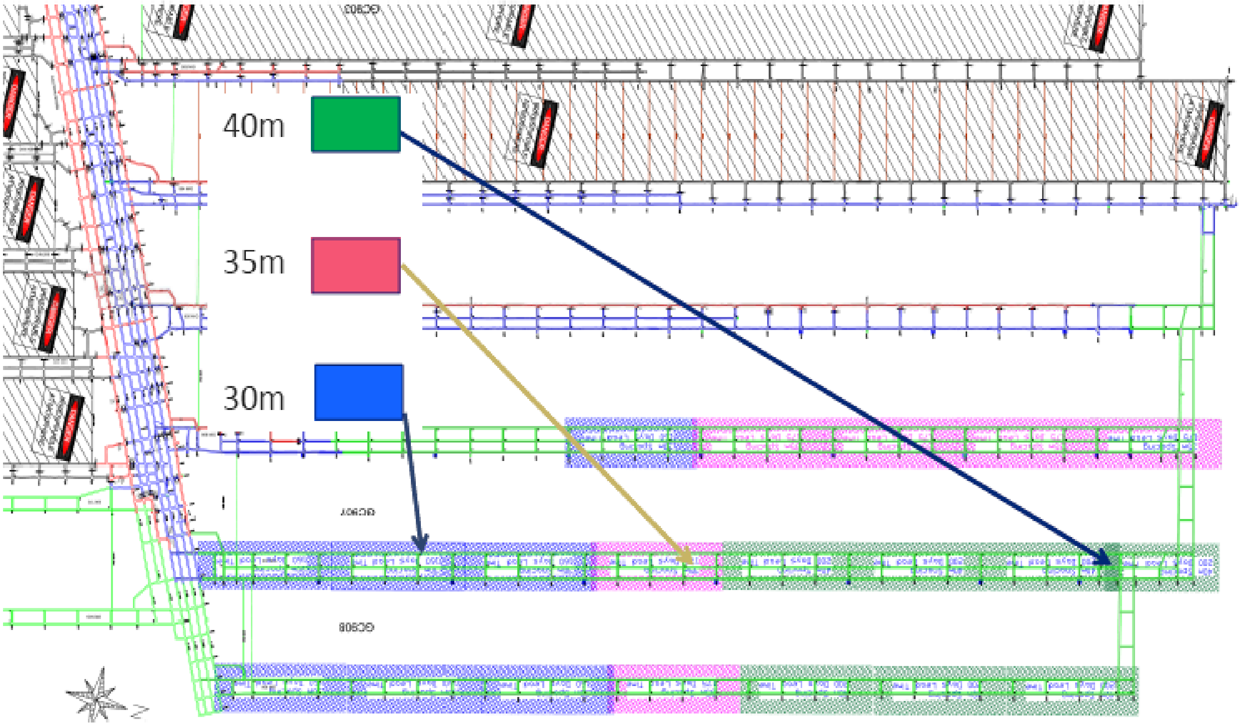

Figure 7: Life of Mine Planning for Drainage hole spacing

UIS Hole Spacing m's	Virgin Gas Content m3/t									
	16	15	14	13	12	11	10	9	8	7
60	322	316	311	305	299	291	281	269	252	228
50	268	264	259	254	249	243	235	224	210	190
45	241	237	233	229	224	218	211	201	189	171
40	215	211	207	203	199	194	188	179	168	152
35	188	185	181	178	174	170	164	157	147	133
30	161	158	155	152	149	146	141	134	126	114
25	134	132	129	127	124	121	117	112	105	95
20	107	105	104	102	100	97	94	90	84	76
15	80	79	78	76	75	73	70	67	63	57

Figure 8: Hole Spacing calculator

Monitoring

The key component to any gas drainage system is acquiring reliable data. Every UIS hole is fitted with a gas flow measuring set outbye of the holes isolation valve. Two styles have been utilised. High flowing holes (>30 l/sec) utilise orifice plate styles. This is so that when the hole is not being measured the inserted orifice plate is removed to stop potential blockages. The Venturi style is employed as required on lower flow holes or lower risk holes.The orifice plate style is the predominant tool. This is because there is less chance of a blockage especially as Grasstree UIS holes release a high volume of material.

Weekly individual hole flow monitoring is in place. This data is placed into operating spreadsheets for determining how the hole is draining against predicted flows. Anomalies identified from these actual vs. predicted flows then allow the site to remedy low flowing holes or analyse high flowing holes. Additionally, holes which are found to have a blockage can then be treated. Furthermore, every surface riser has real time monitoring allowing for accurate calibration of decay curves and reconciliation of results.

Figure 9: Single hole standpipe arrangement with orifice plate

DESIGN – UNDERGROUND GAS DRAINAGE

The key principles to be continually used for an effective design approach are;

- UIS Hole Design
- Infrastructure

UIS hole design

The following diagram depicts the principle design being utilised for remaining LOM UIS drilling. The design variable is the hole spacing at the target future development gate road. Spacing will vary with regards to continuity with development (schedule), gas content variations and lower permeability zones (identified from geological interpretation and micro cleat analysis).

The new UIS design has numerous strengths. These include;

1. UIS hole stability improvement. Previously holes would fail during or after the hole was completed. The majority of these issues occurred on cleat direction where the drill bit struggled to maintain the desired drilling direction. The holes also failed where branches were occurring on the same direction as the cleat. The new design requires branching to avoid cleat directions at all times. The design principle is - "*all branches are to be directed away from cleat angles".* Branches are planned and sequenced to ensure that this occurs. Since the change there have been minimal issues in hole and after completion.

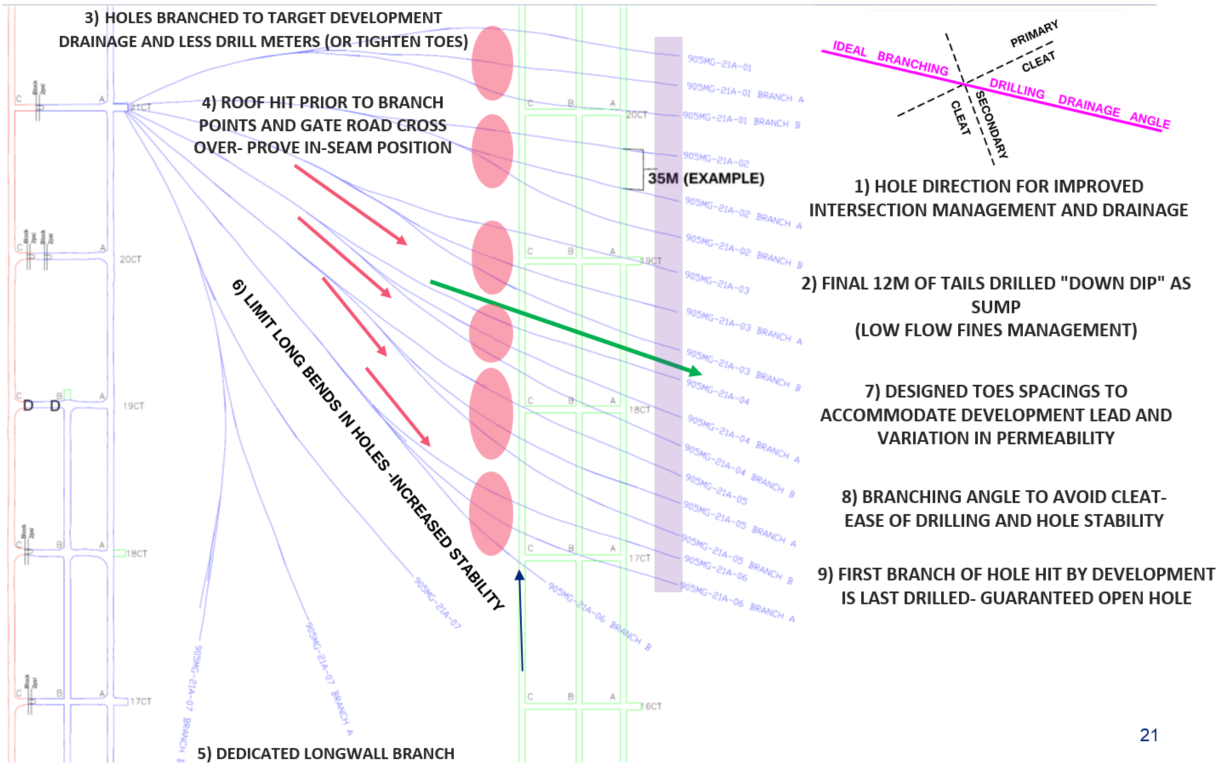

Figure 10: UIS design principles

2. Hole branching. Hole density has increased at the target locations where development are to mine. This is achieved by reducing standpipes and increasing planned branches. This design has an added control that the last branch drilled from any standpipe is the first hole intersected by development. This is to reduce chances of long hole blockages.
1. Hole direction. The design has identified an improved drainage direction when drilling through planned gateroads or zones of very low permeability and drilling difficulty. The additional benefit is that when development intersect these holes in the gate road the virgin side of the hole is in

the rib line while the suction side is in the face. This naturally improves borehole management when developing. Additionally, direction when drilling through geological structures (dykes/fault zones) allows enhanced stability and drainage when the correct angle is chosen.

2. Directional permeability is evident at Grasstree and has been backed by recent micro cleat analysis at UNSW in these zones. Micro cleat analysis validates this assumption as areas of good drainage show a micro cleat clear of obstructions. The new design has rotated the angle of the holes so as to not be parallel with lower permeability directions.
3. Roof touches. All holes require a roof touch prior to drilling across a planned gate roads. This is to acheive highest possibility of the hole being mid seam in these areas, maximising gas drainage. Mid seam intersections on development are far easier to manage.
4. End of UIS hole sump. All UIS holes and branches now have a sump at the end of the holes to accommodate drill fines and reduce chances of holes being blocked upon intersection in development. These sumps are 12 m in length and are drilled down to the floor. Tails are 45 m past the gate road to suit these tails. Additionally these sumps allow flanking drill holes to avoid the end of the holes, reducing the chance of interaction.
5. Virgin gas content cores. At least one core is taken when drilling a full pattern. In conjunction with initial hole flows, an accurate virgin content allows for immediate recalibration of the prediction model. This data is also fed into the "NEW" planning spreadsheet to better plan for how a section is going to be drained.
6. Infrastructure size. Predicting flows is an output of the planning spreadsheet and determines the pipeline and gas riser size. Infrastructure (pipes) needs to suit predicted flows. A single UIS site has recorded flows peaking up to 2500 l/sec which needs to be managed by infrastructure or planning.
7. Fines management. In-hole fines creation occurs during the drainage of the German creek seam. These fines and stone fragments are predominantly emitted into the drill site gas pipework, lifting and removing it when the gas pressure and flow is at it's peak. It is paramount for the infrastructure design to have the abililty to remove this waste underground through a water trap off the range. The remaining fines, so as to not cause a build up or blockage in-hole, are targetted at being deposited in the end of hole sump. The final 12m's of the hole is drilled downwards to create this sump.
8. Structure identification. The UIS design has the ability to be changed where there is an identified or a predicted outburst prone structure(s). "Close the grid" style drilling is used to attempt to locate these structures. It should be noted that small structures are very difficult to predict with UIS drilling as they can be penetrated without noticing changes. These "close the grid" designs can be conducted at the commencement of drilling by "looping" the tails of the holes across each other or just prior to mining by drilling from behind the development operations. The earlier a structure is identified means a lesser chance of a structure being unexpectedly intersected by development. Once structures are identified then additional compliance cores can be designed and conducted prior to development. Figure 11.

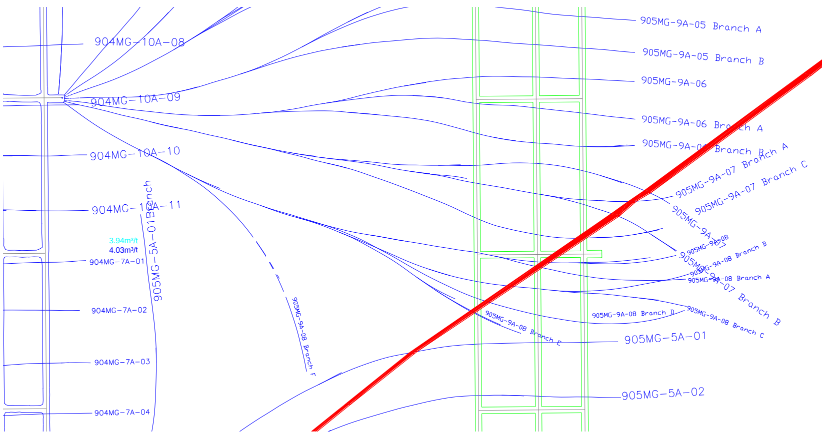

Figure 11 Close the Grid style drilling for structure

9. Standpipe placement. Holes are drilled left to right in a drill site to maximise room for driller operators. Standpipes are limited by the hole spacing. Basically two branches off the trunk are designed for every hole that targets a future gate road. Figure 12.

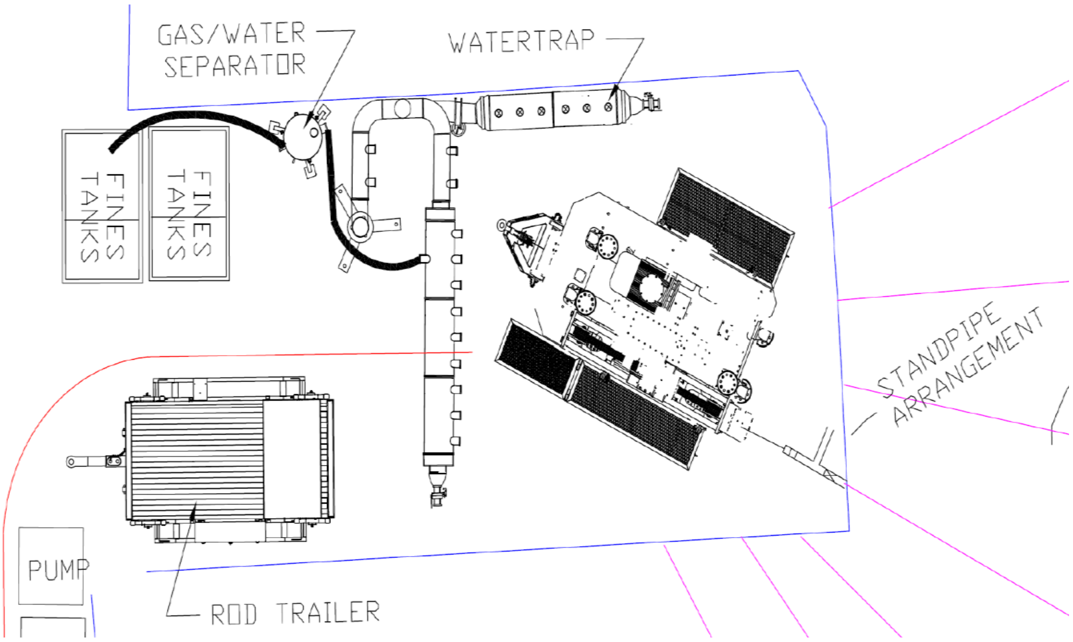

Figure 12: UIS design change

Infrastructure

The current drill site arrangements can relate to both stubs or open sites. The drill site design standard has the objectives of both allowing operators a less conjested site (ergonomical) and provide a separate water and fines system allowing flow to the gas riser.

The arrangement requires flexibilty depending on the location of the riser. Each site will be arranged to suit, however the general layout applies. There must be;

1. A method of isolating water and fines from the riser and pipes in order to remove from the system. (see water trapin Figure 13).
2. Equipment installed for measuring individual hole gas flows, known as Measuring Sets.
3. Infrastructure in line for allowing holes to be unblocked without releasing gas to the atmosphere. This is by a 100 mm (4") to 50 mm (2") t-piece between the standpipe and hole isolation valve.
4. Adequate pipe infrastructure to allow gas to flow to the gas riser with minimal restrictions
5. Pressure monitoring in pipe infrastructure to ensure that the pressure TARP is easily managed. Installing the correct size riser assists with reducing the chances of high pressures. The decision tool for the riser diameter is shown in Figure 14
6. Adequate height differential for separating drillers gas and water/fines to their fines bins. This will minimise water and fines inflow into main pipe range from the drillers.

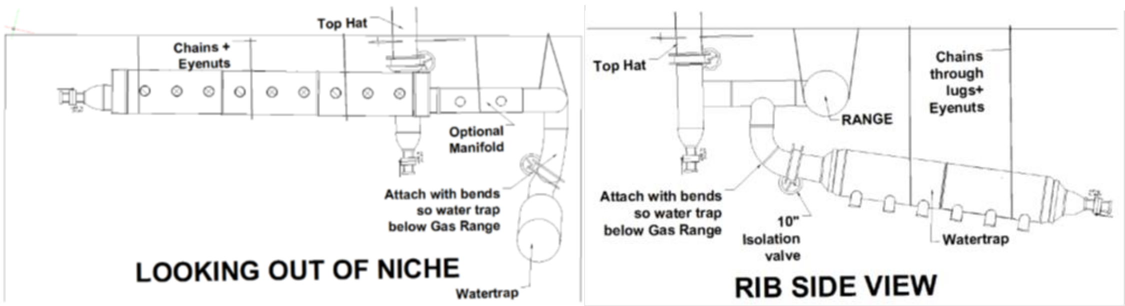

Figure 13: Drill site pipe infrastructure

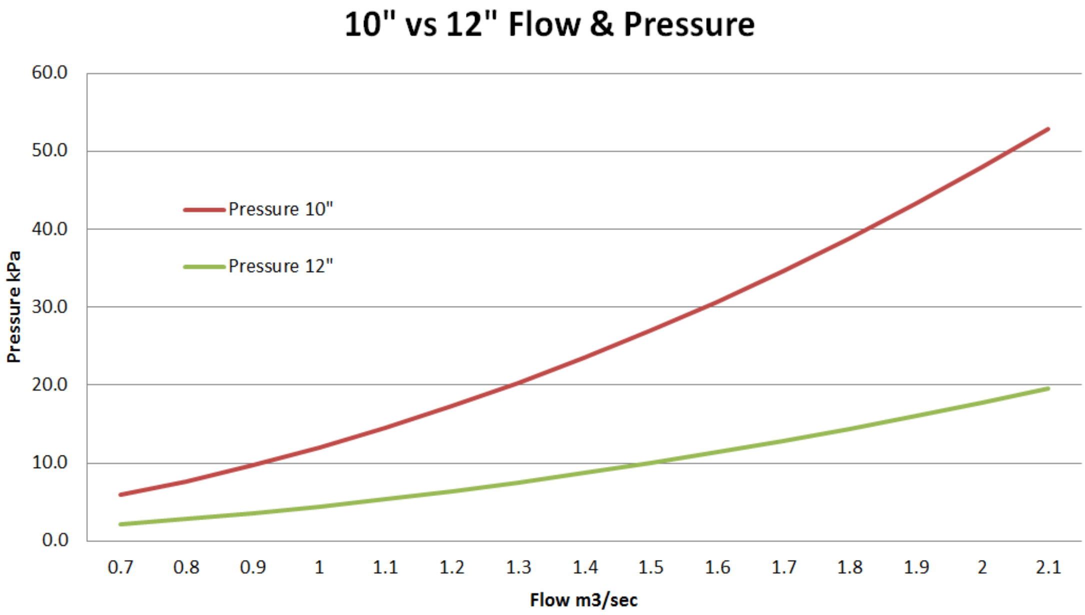

Figure 14: Gas riser diameter prediction tool

RECONCILIATION OF DESIGN

Predicting and monitoring of gas flows and mining gas content

The main output of the prediction and monitoring model is the final gas reconciliation for purposes of guaranteeing precise gas capture from the reservoir, model accuracy and correction and low gas content upon coring and mining. Figure 15.

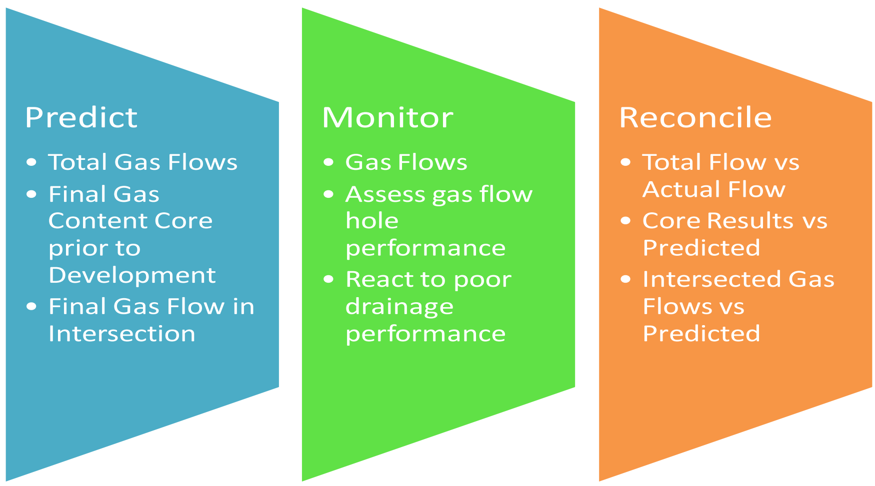

Figure 15: UIS design change

Case Study- 905MG 9ct A Heading

This is the second new style drill pattern to be intersected by development. All core results were below 3 m^3/t and suction was seen at face upon intersection by development for all holes. Figure 16, shows a comparison between actual measured flow rates versus the predicted flow rates for the pattern shown in Figure 19. This actual flow data gathered is used in a process of reconciliation of the individual borehole reservoir to predict residual gas content at desired times to develop robust compliance core schedules to ensure development continuity. This flow data and characteristics is fed back into the decay model by means of comparing gas captured (volume) to the flow rate of the hole at a particular time from commissioning. This makes the prediction of flow rates at a set gas content more accurate for future patterns in similarly permeable areas.

Year	Week Ending																								
Month	1-Jun	8-Jun	15-Jun	22-Jun	29-Jun	6-Jul	13-Jul	20-Jul	27-Jul	3-Aug	10-Aug	17-Aug	24-Aug	31-Aug	7-Sep	14-Sep	21-Sep	28-Sep	5-Oct	12-Oct	19-Oct	26-Oct	2-Nov	9-Nov	16-Nov
Total Flow	0	298	1838	2447	2162	1816	1295	924	684	463	340	281	231	195	165	141	128	117	119	118	113	109	109	109	0
Target Source																									
Hole 2		0	30	309	300	250	180	120	90	80	65	53	45	35	27	21	18	17	15	18	17	15	15	15	
Hole 3		0	190	396	360	320	220	170	120	80	53	46	40	35	30	25	20	18	25	20	18	18	18	18	
Hole 4		0	200	352	330	280	190	140	100	70	47	44	38	30	25	21	19	17	16	17	16	16	16	16	
Hole 5		0	300	315	260	210	170	110	80	42	35	30	26	23	20	18	17	16	15	15	15	15	15	15	
Hole 6	0	30	314	310	280	230	140	100	80	42	35	30	26	23	20	18	17	16	15	15	15	15	15	15	
Hole 7 -	0	90	344	325	295	250	170	100	70	46	35	30	26	23	20	18	17	16	16	16	16	15	15	15	
Hole 8 - Outbye	0	150	450	432	330	270	220	180	140	100	70	48	30	26	23	20	18	17	17	17	16	15	15	15	

	5m3/t
	3m3/t

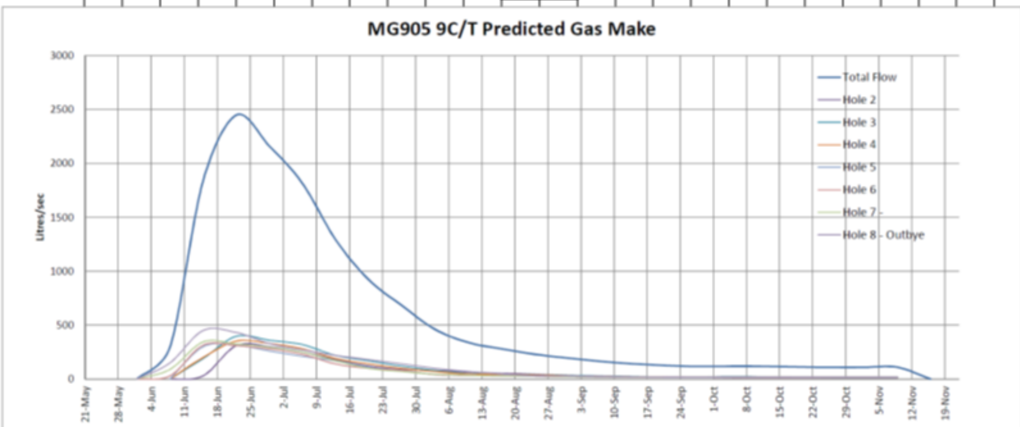

Figure 16: UIS design predicted vs. actual gas make

	Week Ending																											Predicted Vs. Measured as Percentage (m3)			
	1-Jun	5-Jun	12-Jun	19-Jun	26-Jun	3-Jul	10-Jul	17-Jul	24-Jul	31-Jul	7-Aug	14-Aug	21-Aug	28-Aug	4-Sep	11-Sep	18-Sep	25-Sep	2-Oct	9-Oct	16-Oct	23-Oct	30-Oct	6-Nov	13-Nov	20-Nov	27-Nov				
Total Flow	0	538	1227	2044	1799	1301	935	715	654	1144	1071	854	633	470	406	300	263	225	202	183	176	148	125	141	141	122	104				
Hole Number																													Predicted	Measured	
Hole 2	0	225	358	432	295	211	160	144	106	86	72	63	58	56	42	37	35	29	25	23	22	16	11	16	16	14	13		1151547	1525306	132%
Hole 3	0	313	376	452	343	236	186	144	125	96	75	64	58	50	49	30	30	28	25	23	22	19	16	21	21	17	13		1196068	1681949	141%
Hole 4								0	0	250	433	330	208	112	93	72	49	44	39	34	33	29	26	27	27	23	19		1053562	1075939	102%
Hole 5		0	273	435	336	273	174	133	111	87	76	59	45	44	44	23	27	22	20	18	19	16	12	17	17	16	15		1182358	1369267	116%
Hole 6		0	110	375	393	266	160	120	90	61	59	56	50	44	44	25	27	24	21	19	20	16	13	17	17	15	13		1066682	1215648	114%
Hole 7 -		0	110	350	432	315	255	174	142	104	103	81	61	52	51	31	27	27	25	22	23	18	16	15	15	13	11		1092972	1472083	135%
Hole 8 - Outbye								0	80	460	253	201	153	112	83	82	68	51	47	44	37	34	31	28	28	24	20		965261	1066867	111%
																												Total	7708448	9407059	122%

	5m3/t
	3m3/t

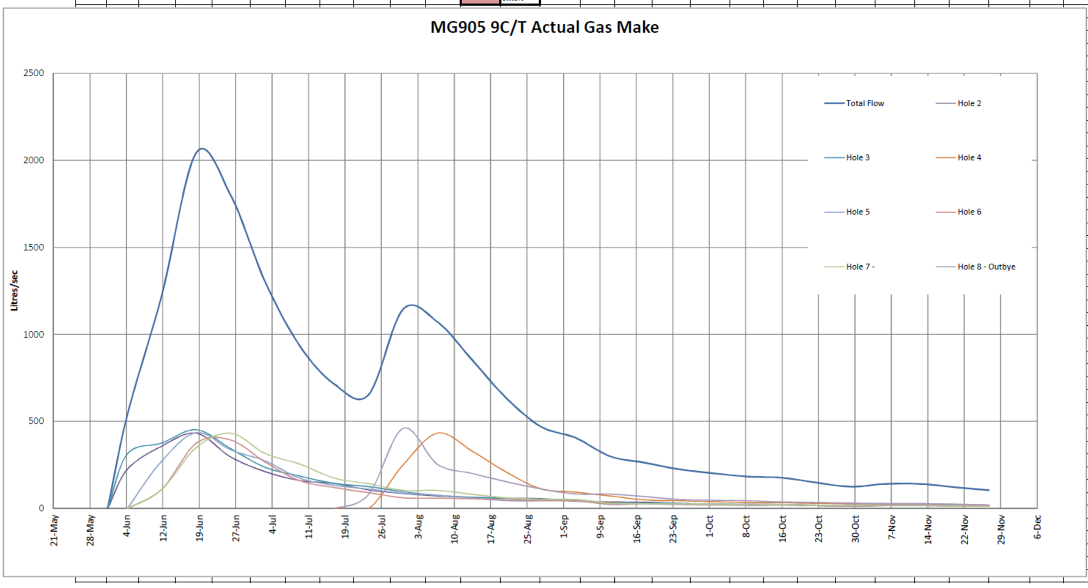

Figure 17: 905MG 9ct actual drilling and compliance results

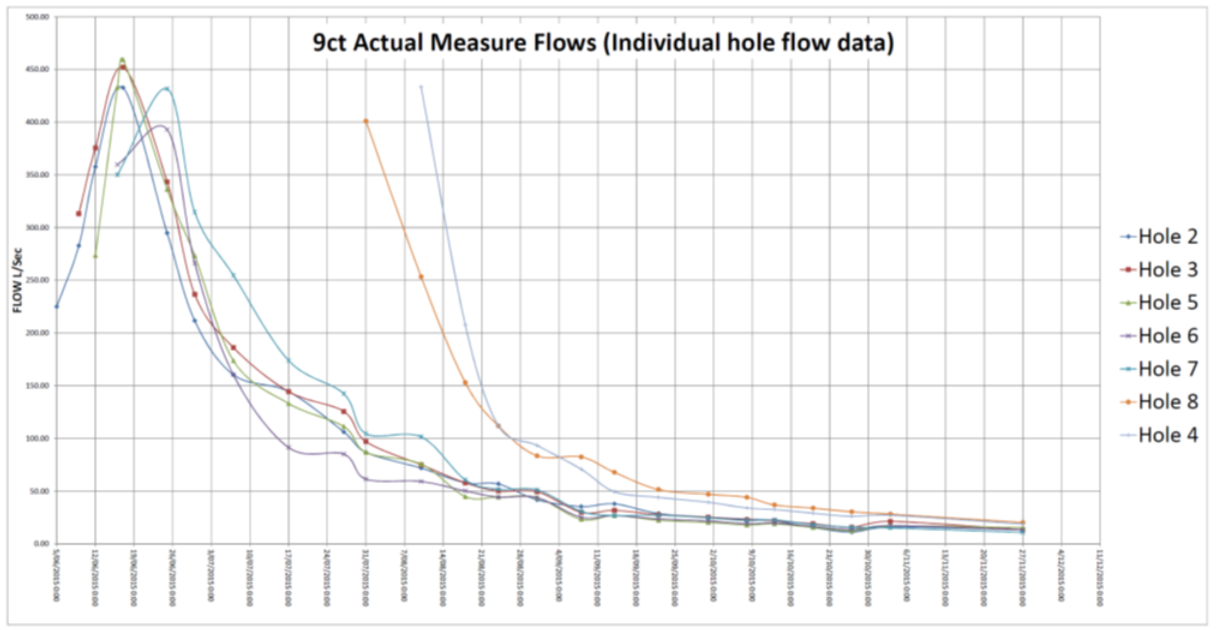

Figure 18: 905MG 9ct actual individual hole flows

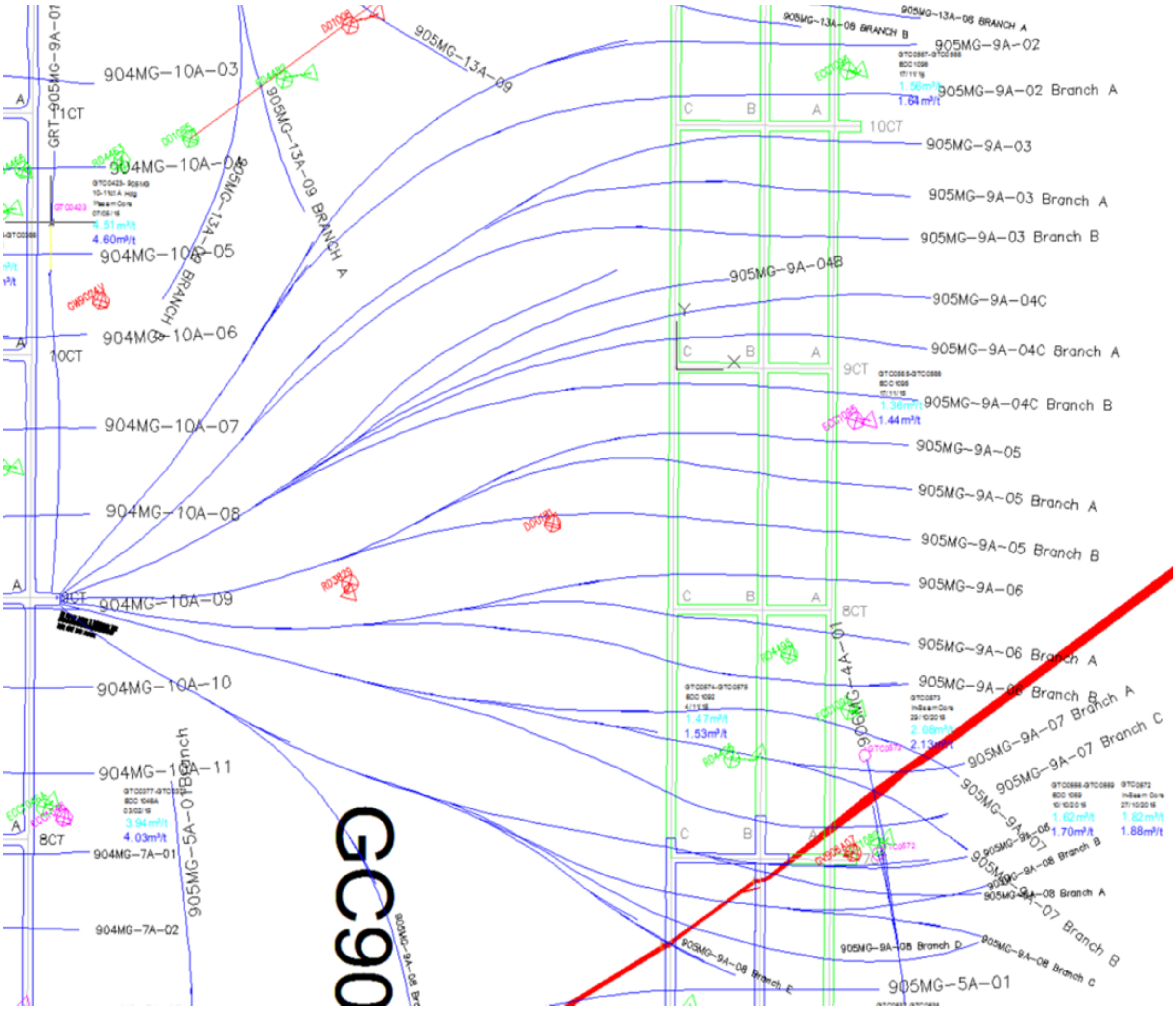

Figure 19: 905MG 9ct actual individual hole flows

Holes	Target Zone	Start	Finish	Hole spacing	Drilling meters	Virgin Gas Content	Target Gas Content	Area to Drain m2	Ave Seam Thickness	Tonnes Coal to Drain	Vol of gas to remove m3	Start date of gas Flow to pipe	Expected Time to drain to target (Days)	Required Finish date to Drain to target	Required time to drain to target	Continuity with Development	Peak Flow l/sec	Flow prior to Mining l/sec	Cored Content m3/t	Probable Gas Content when Mined m3/t
PRE-DRAINAGE																				
9C/T 905	906 7-10C/T																			
Hole 2	10-11 c/t	1/06/2015	4/06/2015	25	1299	16	3	23434	2.7	88581	1151547	4/06/2015	102	23/11/2015	14/09/2015	70	432	16		1.95
Hole 3	9-10ct	4/06/2015	6/06/2015	25	1242	16	3	24340	2.7	92005	1196068	6/06/2015	104	18/11/2015	18/09/2015	61	452	21		1.9
Hole 4	9ct	31/07/2015	3/08/2015	25	1761	13	3	27872	2.7	105356	1053562	3/08/2015	81	13/11/2015	23/10/2015	21	433	27		2
Hole 5	8-9 ct	8/06/2015	9/06/2015	25	1161	16	3	24061	2.7	90951	1182358	9/06/2015	98	8/11/2015	16/09/2015	53	435	17		2.5
Hole 6	8 ct	10/06/2015	12/06/2015	25	1179	16	3	21707	2.7	82052	1066682	12/06/2015	97	3/11/2015	17/09/2015	47	393	17	1.68	1.6
Hole 7 -	7 -8 ct	12/06/2015	14/06/2015	25	1573	15	3	22242	2.7	84075	1008897	14/06/2015	103	29/10/2015	21/09/2015	38	432	15	2.13	1.9
Hole 8 - Outbye	7 c/t and LW Block	24/07/2015	31/07/2015	20	2206	11	3	31920	2.7	120658	965261	31/07/2015	75	30/10/2015	14/10/2015	16	460	28	1.79	1.7

Figure 20: UIS reconciliation tool

ADDITIONAL IMPROVEMENTS

Microcleat analysis

Although it has been identified through monitoring that there are definite zones of lower permeability (lower gas flow) the reason has not been proven. Dr Lila Gurba from the University of New South Wales was engaged to analyse coal samples for potential flaws to coal gas flow. These tests also looked at areas where there were poor gas drainage flows and good gas drainage flows encountered. These tests were at a micro level.

The analysis has shown a definite directional issue with micro cleats thwarting gas migration in one direction. The direction is clear and appears to be sheared closed hence the poor gas flow. More analysis is to continue.

Extended Q1 analysis

Grasstree mine utilises both surface and underground coring for both compliance gas content cores and virgin gas content core data. To take a core from underground at a distance which would normally take greater than 40 minutes to place under test, the site required a method to be acceptable to allow this to occur. GeoGAS was engaged to provide a correction factor for this purpose.

The following diagram represents Grasstree Q1 correction factor for when cores take greater than 40minutes to be put onto test. The advantage of this test increases the use of longer cores or cores where there were issues recovering, providing data well before current time limits allow.

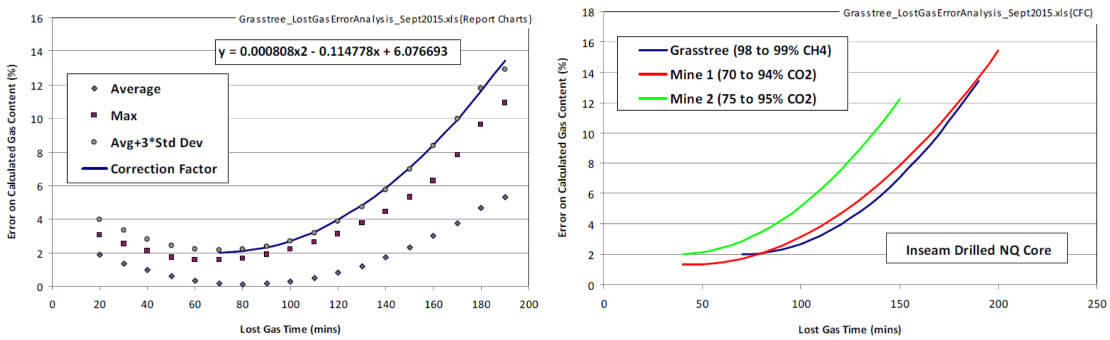

Figure 21: UIS design change

Borehole intersection suction level TARP

Creating a TARP for suction levels prior to development intersection is the final key to the puzzle for improving mine safety for UIS drainage vs development interaction. Improvement and quality standards of roadway hose over standpipes and methods is also vital to successful gas control post intersection.

CONCLUSIONS

The development of a reconcilable underground gas drainage system is the key to sustaining effective gas drainage for the remainder of the mines life. This system must and can cover all changes in coal characteristics in relation to varying gas content and effects from geological structures. The following points highlight the success of this system.

- Underground Inseam hole gas flow is able to be estimated accurately with or without permeability data. Variable decay curves can be created and calibrated with regards to different coal characteristics
- Understanding microstructure is vitally important to understanding hole flow variations. Also a link with mircocleat issues and outburst prone structures or even coalburst characteristics
- Correct Infrastructure design (size) is required to limit reduce gas pressure increases from hole flows or from gas surging. This includes gas pipe or gas riser diameter
- Being able to reconcile the complete design of a gas drainage system in regards to its performance versus planned is vital for not just approval to mine but for the workforce confidence, especially for such a gassy operation.
- Designing a system that sets standards for suction levels required to be applied to UIS holes prior to developing thru is a massive step in reducing potential for gas incidents in development faces.

The final hurdle is the opinion of the crews and staff at site. The support for change was always positive, however the results and confidence gained for the current management of gas drainage is justified. Providing a new handbook for all aspects of Underground gas drainage now allows all on site to understand the volume of processes conducted at Grasstree. This handbook will be used for all training aspects of gas Drainage and as a support document to Principle Hazard Management Plans.

ACKNOWLEDGEMENTS

The opportunity and financial support provided by AngloAmerican and the Grasstree Mine to undertake this work is greatly appreciated. The assistance and input provided by Drive Mining Pty Ltd and in particular Miles Brown is also acknowledged.

Dr Lila Gurba from the UNSW has provided analysis of coal properties at the microstructure level and Geoff Williams from GeoGAS for completing the extended Q1 Analysis

REFERENCES

Williams, G, 2015. Lost Gas Error Analysis – Grasstree Mine. *Report No.: 2015-1310 / November 2015. GeoGAs Pty Ltd*.